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FLYING, MAINTENANCE, AND THE SALE OF PARTS TO THE FIELD: INTERACTIVE MODELS FOR AH-1 AND CH-47 SYSTEMS

Valentin C. Berger
Blaine T. Stone

April 1977

Final Report

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

U.S. ARMY AVIATION SYSTEMS COMMAND
Systems Analysis Office
Operational Systems Analysis Division
P.O. Box 209
St. Louis, Missouri 63166

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Sale	AH-1	
Parts	CH-47	

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Computer-generated graphic displays are used to investigate the relationships of AH-1 and CH-47 fleet flying hours, and of maintenance occurrences of short and long duration during selected peacetime and wartime (RVN) periods. The rationale for observed relationships is explored in detail, and the discussion is supported with the results of correlation analyses.

A similar approach is used to explore the relationships existing between monthly gross sales of stock-funded airframe parts to the field and the number →

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20. ABSTRACT (Continued)
(fr p iii)

of short and long duration maintenance events, and between those sales and monthly fleet flying hours. The AH-1 and CH-47 fleets are examined during a peacetime period of ~~one and one-half~~ 1-1/2 fiscal years.

The two elements of the study are shown to be complementary and suitable for the construction of interactive models of operations and supply support.

A probable connection is postulated between managed field maintenance support activities and the cost-effectiveness of On Condition Maintenance (OCM) world-wide team visits.

Conclusions summarizing the findings of this study, and proposing complementary research projects, terminate the report.

ACKNOWLEDGMENTS

The authors are indebted to Mr. Jack R. Isom, Chief, Policy, Plans, and Programs Division, USAAVSCOM Directorate for Materiel Management, for the cost data used in this study, and for his sustained and constructive support of our efforts.

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I. INTRODUCTION

Beginning in March of 1975, AVSCOM's Systems Analysis Office became engaged in an extensive review of maintenance float operations, and developed a novel technique for the computation of Operational Readiness Float (ORF) factors. Details of this project, and the technique itself, are presented in USAAVSCOM Technical Report 77-19 (U), dated March 1977 (Reference 1). Although the new technique and its results were fully accepted by HQ DA, the authors felt that additional understanding of the interactions between operational flying, maintenance and repair events, and parts sales to the field was needed and could be achieved. Specific interest centered upon two issues: the unexpected associations of low flying hour rates with high rates of maintenance/repair events; and the poor-to-marginal quality of correlation models relating flying hour rates and the monthly number of repair events exceeding the duration limits of AR 750-1 (Reference 2). This study report presents research performed to increase our knowledge of these phenomena and of their most probable causes.

II. METHODOLOGY

Research methodology for this project is oriented by formulating three "hypotheses" corresponding to an assessment of logical relationships between flying, maintenance, and parts sales:

a. Flying stresses generate maintenance and repair requirements;

b. Maintenance activities "consume" parts, and create thereby the demand for a forward flow of parts to the field;

c. The above activities are sequenced, and continue over measurable periods of time.

The preceding hypotheses have the following inferred consequences:

a. Monthly flying time hours should correlate (well) with monthly "maintenance" and "repair" event counts;

b. Monthly flying hours should correlate (well) with monthly gross sales of parts to the field; and

c. The above correlations should improve statistically by accumulating (over time) flying hours, maintenance events, and dollar costs, and by offsetting in time (prior to correlation analysis) those activities which are sequenced in real life.

The technique of correlation analysis is used in this study to determine whether the hypotheses and their consequences represent operational reality. Automated graphic comparison techniques are used to provide a basis for understanding imperfect correlations where they occur. All of the illustrations and figures shown in this report represent "optimized" results of computerized correlation analyses, i.e., those results based on time offsets and/or accumulations that yield the highest possible Index of Determination (R^2). The

AH-1G and CH-47 systems airframes are used to illustrate the application of the foregoing methodology to operational (Reference 3) and cost data (Reference 4).

III. FINDING AND DISCUSSION: FLYING HOURS IN PEACETIME

A logical introduction to this study, given the presumed dependency of all activities upon flying hours, is to examine the pattern of flying hour programs during one-and-one-half peacetime fiscal years (July 1974 thru December 1975).

Figure 1 shows traces of Fleet Flying Hours for four first-line Army aircraft systems during the period of interest. A striking similarity may be observed in the rise and fall of these curves. Months #1 and #13 (July 1974 and July 1975) are "mid-lows" in terms of flying hours, reflecting transitions from year-end funds shortages to the effective utilization of new monies. Months #2 thru #5 and #14 thru #17 are "mid-highs" brought about by a combination of availability of funds and good flying weather. The months of December 1974 and, presumably, December 1975 (#6 and #18) precede substantial drops in flying hours attributable to the holiday season and to deteriorating weather. The low-ebb month, #7 (January 1974) is common to all systems and precedes the spring revival of flying which peaks in months #11 and #12, May and June of 1974. The highs of those months are attributed to steadily improving weather, to scheduled maneuvers of joint combat arms, and to a determined year-end effort to make effective use of residual funds. July 1975, month #13, ushers in a new cycle of interplay between funds flow and utilization, weather, and annual holiday/vacation practices.

FLEET FLYING HOURS WORLDWIDE

AH-1, CH-47, UH-1, OV-1

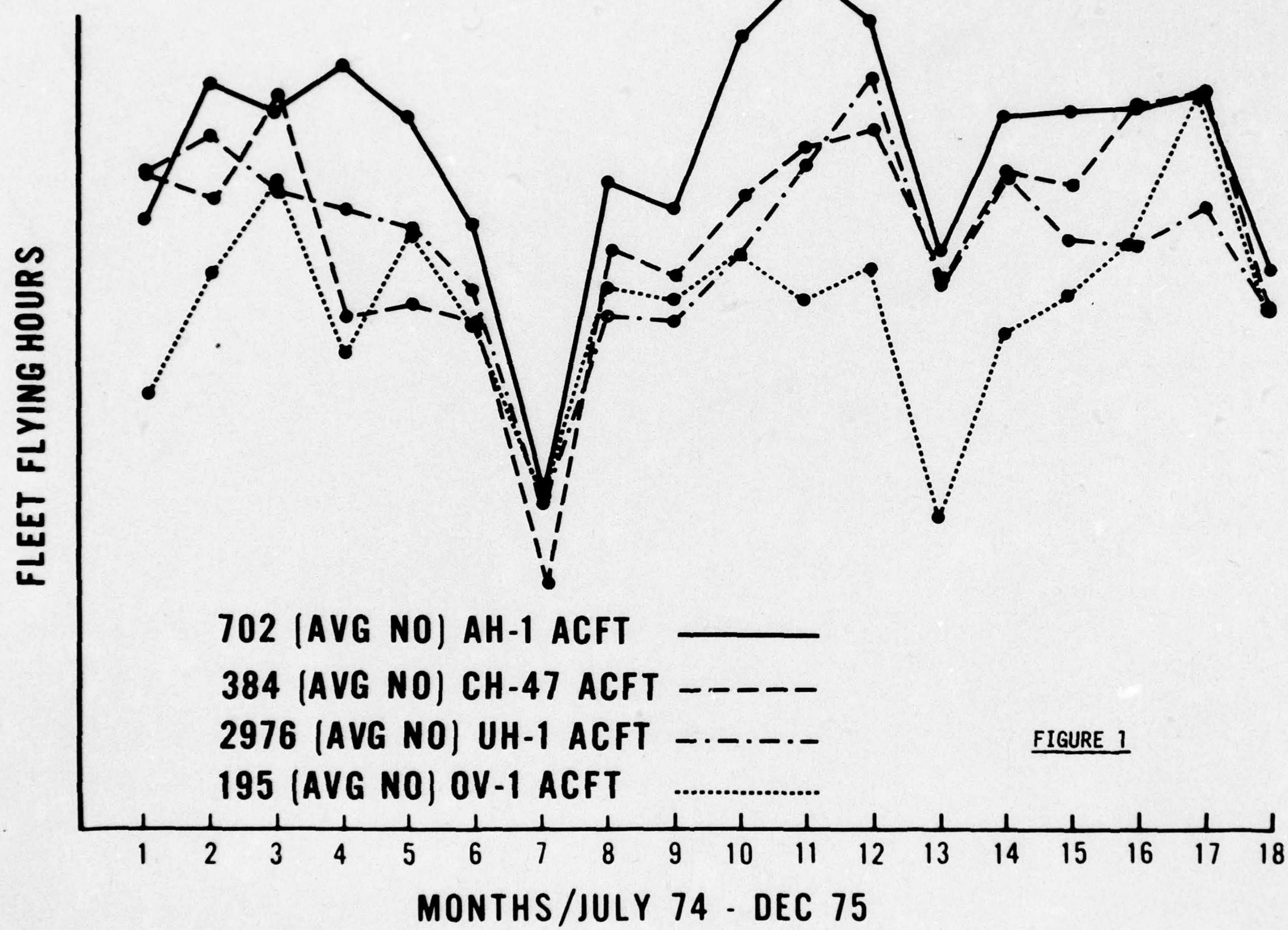


FIGURE 1

IV. FINDINGS AND DISCUSSION: MAINTENANCE AND REPAIRS OF AH-1 SYSTEMS IN PEACETIME

The flying hour patterns of Figure 1 are well-defined, with distinct highs and lows. Figure 2 reproduces the AH-1 fleet flying hours trace of Figure 1, leaving out the vertical scale numbers, together with traces of maintenance event occurrences requiring, respectively, 1 to 7 days and 8 to 31 days. The vertical scale of Figure 2 displays the number of occurrences of the shorter duration events ("maintenance") and of the longer events ("repairs") during the July 1974 - December 1975 period. The choice of 8 days duration as a differentiator between maintenance (NORM + NORS) and repairs (NORM + NORS) is related to current repair time limits governing the assignment of float aircraft to losing units.

A coordinated review of the three traces of Figure 2 yields the following observations:

a. The "maintenance" events count trace demonstrates large month-to-month count excursions somewhat in lock-step with the flying hours representation. Coincident low points are months #1, #7, and #18. A case may be made from the proximity of month #12 (1 - 7 days trace) and month #13 (Fleet Flying Hours trace). The correlation of high points is less obvious on a month-by-month basis; it is nevertheless apparent that months #2 thru #6 and #8 thru #17 comprize periods of rough covariance. In support of these observations a correlation analysis of flying hours and "maintenance" occurrences generates a parabolic model* with an R^2 of 0.46. It is noted that this R^2

* $Y = -2583.95 + 121.22X - 0.44X^2$

value is rather low, signifying a marginal correlation of flying hours and short-term maintenance occurrences.

b. The "repair" events count trace demonstrates relatively small month-to-month frequency excursions, and virtually no correspondence to the fleet flying hours representation. Analysis of these two traces generates a parabolic model** with an R^2 of 0.05, signifying no correlation whatsoever.

c. Except for marginally discernible simultaneous "lows" in months #1, #7, and #18, the representations of "maintenance" and "repair" occurrences appear to be unrelated. It is noted, however, that periods exist where the count of "repairs" increases as the count of "maintenance" events decreases. These periods span months #1 thru #2, #3 thru #6, #9 thru #15, and #16 thru #17.

The preceding observations indicate that during the peacetime period July 1974 thru December 1975 short-term maintenance (1 - 7 days) activities and, more notably, longer-term maintenance (8 - 31 days) operations were "de-coupled" from the turbulent ebb and flow of the flying hours program. It is conjectured that this condition was effected deliberately in the field, in order to distribute maintenance work evenly through time. It is also conjectured that the monthly maintenance burden was further reduced and distributed in the field by incorporating, whenever possible, short-term maintenance work into longer duration repair-oriented activities. It appears that, given a fixed-size force of maintenance personnel and a fluctuating flying hours

** $Y = -7608.34 + 127.95X - 0.31X^2$

program, field officers maintain DA-mandated operational readiness (OR) standards by managing the processes of "cutting and filling" and of maintenance/repairs integration evidenced in Figure 2.

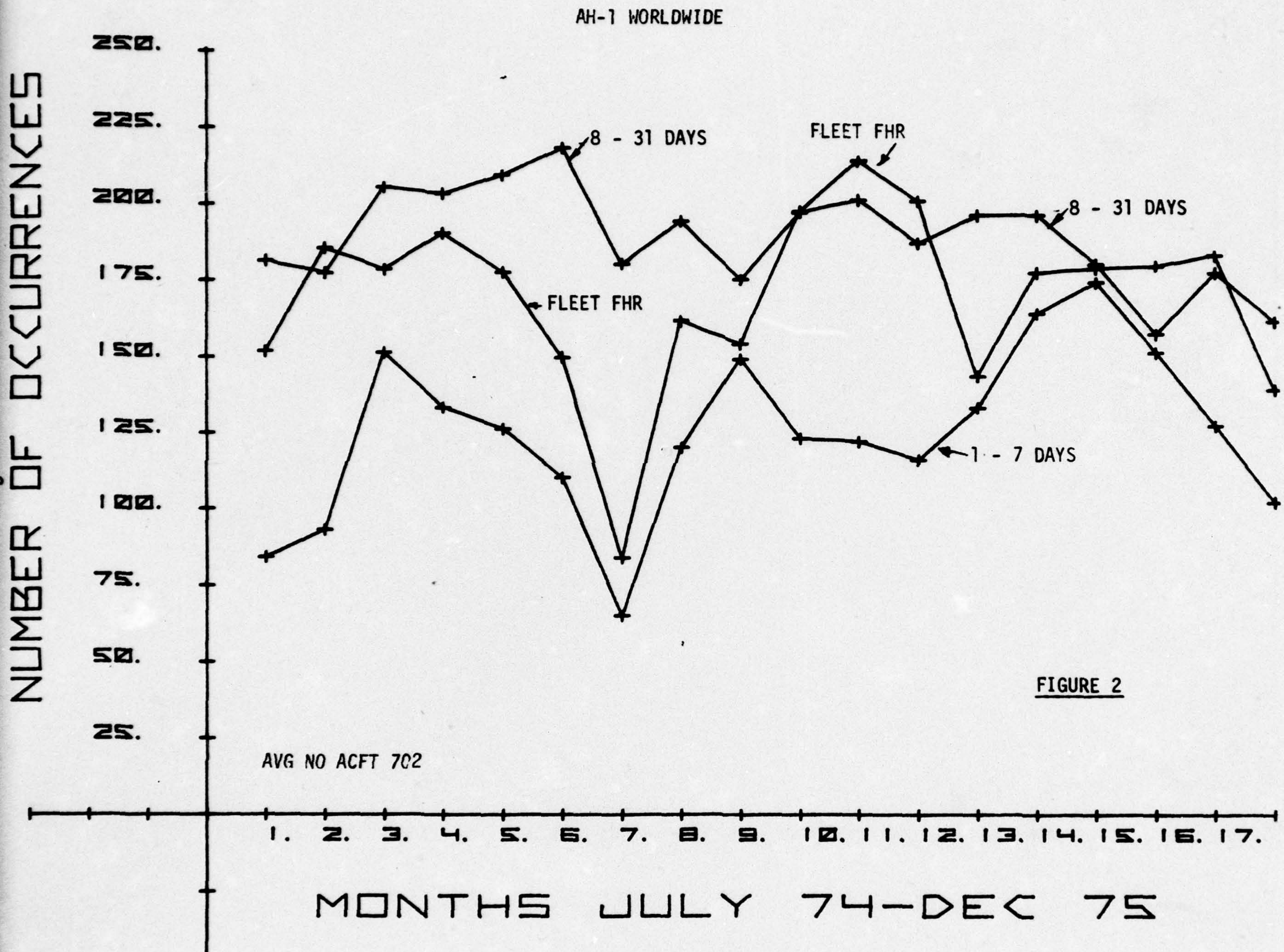

AH-1 WORLDWIDE
NUMBER OF OCCURRENCES
250.
225.
200.
175.
150.
125.
100.
75.
50.
25.
8 - 31 DAYS
FLEET FHR
8 - 31 DAYS
FLEET FHR
1 - 7 DAYS
AVG NO ACFT 702
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17.
MONTHS JULY 74-DEC 75

FIGURE 2

V. FINDINGS AND DISCUSSION: MAINTENANCE AND REPAIRS OF AH-1 SYSTEMS IN COMBAT

Figure 3 contains displays similar to those in Figure 2 for the period July 1968 thru December 1969. Data shown pertains exclusively to that portion of the AH-1 fleet engaged in combat operations in Southeast Asia (RVN).

A review of Figure 3 shows considerable variance with reference to Figure 2:

a. The traces of shorter-term "maintenance" event counts and of longer-term "repair" occurrences are switched in their relative positions. Maintenance events each month exceed repair occurrences by an average of 3 to 1.

b. Both short-term and longer-term maintenance event count traces show little month-to-month fluctuations.

c. The Fleet Flying Hours trace evidences none of the variations associated with funds flow and utilization, or with holidays and vacations, during peacetime years.

d. There appears to exist a close and significant correlation between the trends of fleet flying hours and (1 - 7 days) "maintenance" events frequencies. This correlation is most marked during the period July 1968 thru February 1969 (months #1 thru #8), and continues in more irregular detail thru month #18. Analysis indicates an R^2 of 0.95 for the parabolic model* of this relationship.

* $Y = -7845.70 + 237.09X - 0.29X^2$

e. By way of contrast, there exists little significant correlation between fleet flying hours and (12 - 31 days) "repair" event occurrences. Analysis indicates an R^2 of 0.39 for the parabolic model** of this relationship.

The preceding observations indicate that during mid-intensity combat years short-term maintenance activities in support of gunships were closely associated with flight operations, with a "steady-state" regime of repairs relegated to second place. Management stress was placed on keeping aircraft in the air, and on maintaining a high rate of operational readiness (OR). It is conjectured that the relatively low level of field repair activity in RVN was backstopped by overhaul operations in CONUS or on board the FAMF in RVN territorial waters. It is concluded that in both peace and war times, the military community adjusts maintenance support policies to maintain or to exceed standard OR rates in complex, shifting, and widely-differing operational environments.

** $Y = -81184.78 + 2633.84X - 16.06X^2$

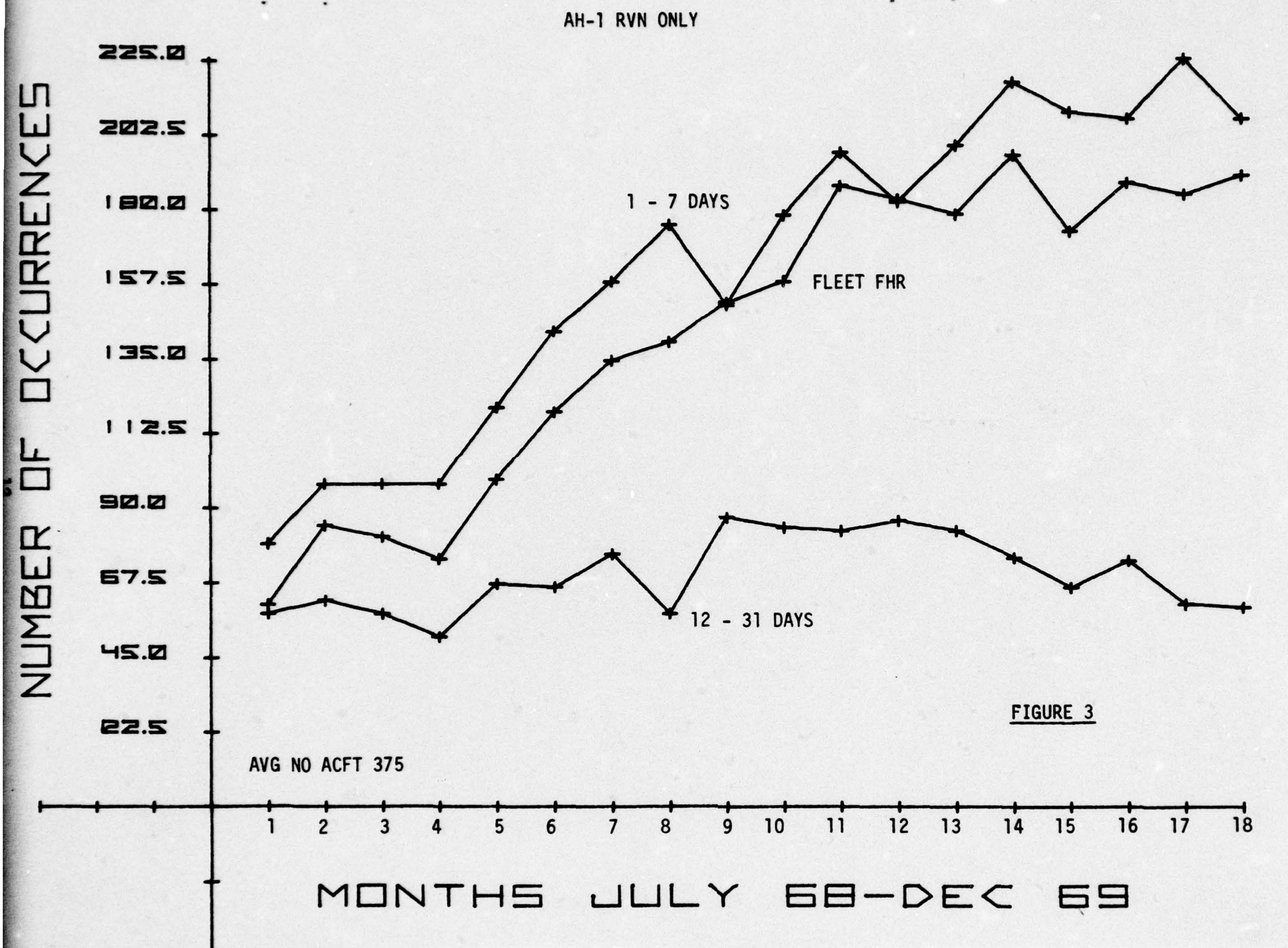

AH-1 RVN ONLY
NUMBER OF OCCURRENCES
225.0
202.5
180.0
157.5
135.0
112.5
90.0
67.5
45.0
22.5
1 - 7 DAYS
FLEET FHR
12 - 31 DAYS
AVG NO ACFT 375
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
MONTHS JULY 68-DEC 69

FIGURE 3

VI. FINDINGS AND DISCISSION: MAINTENANCE AND REPAIRS OF CH-47 SYSTEMS IN PEACETIME

Figure 4 reproduces the CH-47 fleet flying hours trace of Figure 1, omitting the vertical scale numbers, together with traces of maintenance occurrences requiring, respectively, 1 to 7 days and 8 to 31 days, including NORS and NORM times. The study period is July 1974 thru December 1975.

Coordinated review of the three traces of Figure 4 yields the following observations:

a. Neither the short-term "maintenance" events count trace, nor the longer-term "repair" events count model, demonstrate month-to-month excursions proportional to those of the flying time representation.

b. A general covariance of the "repair" occurrences model and of the fleet flying hours trace is apparent. Their trends coincide rather weakly during months #2 thru #7, and more strongly during months #8 thru #18. Correlation analysis of these data collections yields a parabolic model* with an $R^2 = 0.25$, denoting very poor statistical correlation during the full 18-month span of time.

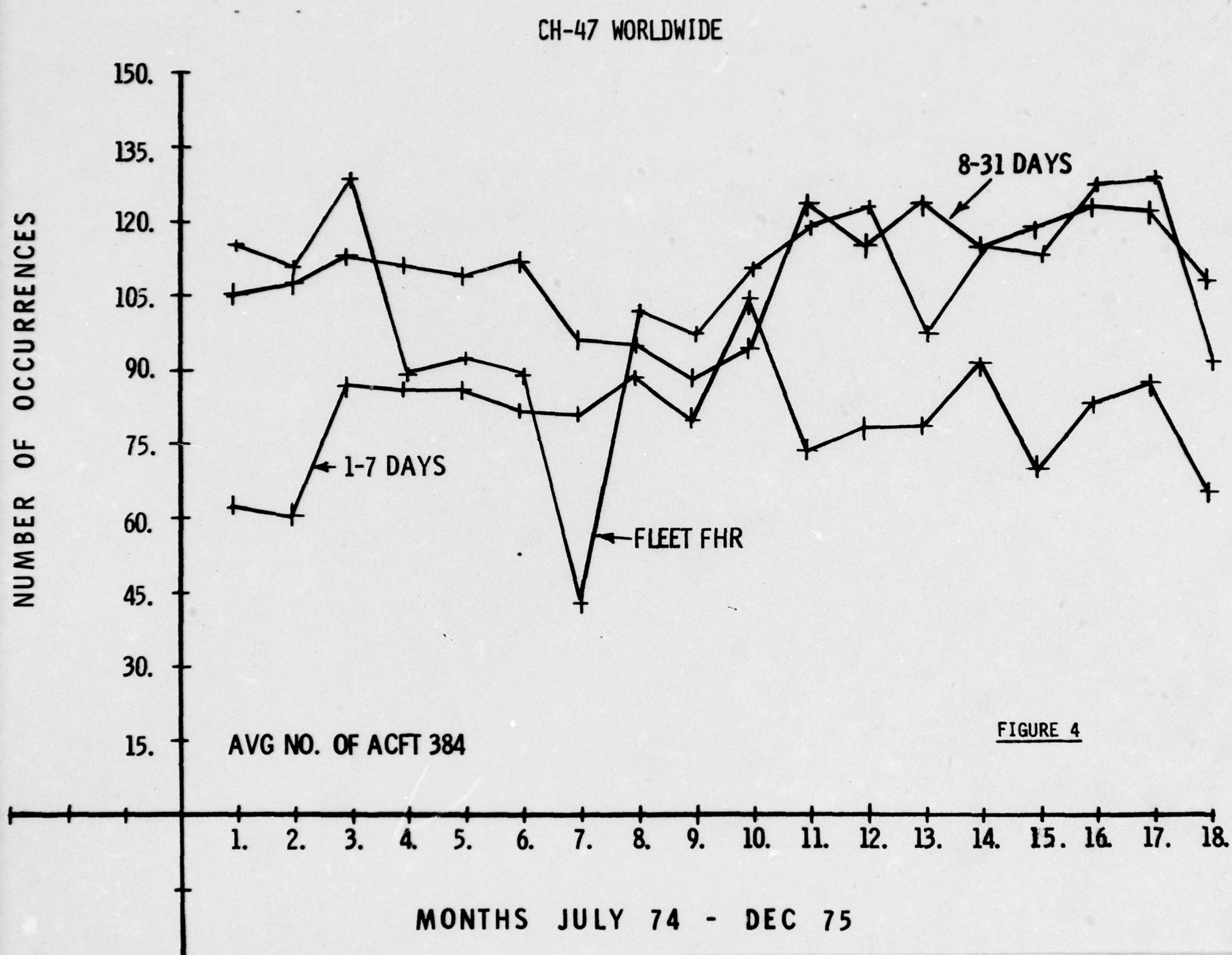
c. Although occasional coincidence in trends may be noted with reference to the "maintenance" occurrences model and the fleet flying hours trace, there appears to be no correlation whatsoever between these data collections. The parabolic** model of the relationship is characterized by an R^2 of 0.03.

* $Y = 9938.40 - 156.07X + 0.88X^2$

** $Y = 7827.25 - 107.25X + 0.65X^2$

d. Except for marginally discernible simultaneous "lows" in months #1, #9, and #18, the traces of "maintenance" and "repair" occurrences appear to be unrelated. It is noted however, that longer-term "repair" events are substantially more frequent than the "maintenance" occurrences. The average ratio approximates 1.4 "repairs" per "maintenance" event, not unlike the ratio computed for the (AH-1 systems) models shown in Figure 2.

The preceding observations indicate that during the peacetime period July 1974 thru December 1975, policy and practice deliberately "de-coupled" the execution of all maintenance support activities in the field from the cyclical variations of the CH-47 fleet flying hours program. It is proposed that the comments relating to the AH-1 System (See Section IV. above, following paragraph c.) apply as well to the CH-47 fleet.



CH-47 WORLDWIDE
NUMBER OF OCCURRENCES
150.
135.
120.
105.
90.
75.
60.
45.
30.
15.
8-31 DAYS
1-7 DAYS
FLEET FHR
AVG NO. OF ACFT 384
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18.
MONTHS JULY 74 - DEC 75

FIGURE 4

VII. FINDINGS AND DISCUSSION: MAINTENANCE AND REPAIRS OF CH-47 SYSTEMS IN COMBAT

Figure 5 contains displays similar to those in Figure 4 for the period July 1968 thru December 1969. Data shown pertains exclusively to that portion of the CH-47 fleet deployed in RVN.

A coordinated review of Figure 5 shows considerable variance with reference to Figure 4:

a. The Fleet Flying Hours trace evidences none of the cyclical fluctuation patterns associated with peacetime operations.

b. Both short-term and longer-term maintenance event count models show substantial month-to-month variations. These variations exhibit a pattern of "cross-overs" between months #3 and #4, between months #6 and #7, between months #7 and #8, and between months #11 and #12, with "maintenance" event counts dominant in the first, third, and fifth periods, and with "repair" event counts dominant in the second and fourth periods.

c. Correlation analyses of "maintenance" and "repair" event occurrences and fleet flying hours (1 - 7 days and 12 - 31 days duration, respectively) generate parabolic functions with R^2 values of 0.32* and 0.11**. Neither of these values is indicative of statistically significant correlation. It is noted, however, that the <u>sums</u> of monthly "maintenance" and "repair" events during the study period vary little from a mean value of 185 occurrences

* $Y = 10733.77 + 126.04X - 0.62X^2$

** $Y = 10958.77 + 137.30X - 0.75X^2$

per month. This minimal variation appears to parallel the minimal contemporaneous variation of the fleet flying hours program.

The preceding observations indicate that for the complex CH-47 aircraft, combat operations were supported by a mix of short-term and longer-term maintenance activities. It is presumed that during those periods when 1 - 7 days duration events are more frequent than 12 - 31 days occurrences, certain maintenance actions were deferred. When the monthly counts are reversed, deferred actions were executed together with some of the shorter-term (1 - 7 days) maintenance. This process is seen as a managed effort to achieve requisite operational readiness (OR) levels with a relatively constant input of maintenance labor.

With reference to the findings and discussion concerning the AH-1 systems in combat (See Section V), the different missions of the Cobra and Chinook are seen as important differentiators in their flying/maintenance relationships. In combat the (AH-1) gunships were engaged in frequent sorties forward of the FEBA, resulting in firefights, while CH-47 aircraft were used to transport supplies and materiel behind the FEBA. This definition of their respective missions supports perceived differences: short-term maintenance activities were used to keep AH-1 aircraft fighting, while a mix of short-term and longer-term activities was employed to keep the CH-47 aircraft capable of carrying cargo. The typical AH-1 system was either repatriated for overhaul/rebuild, or was sufficiently well served by intensive short-duration maintenance and by a relatively low level of deferred longer-term repairs. The CH-47, on the other hand, could be effectively serviced and maintained in the field, with routine cut-and-fill deferrals of longer-duration actions required to keep this mechanically complex aircraft airworthy.

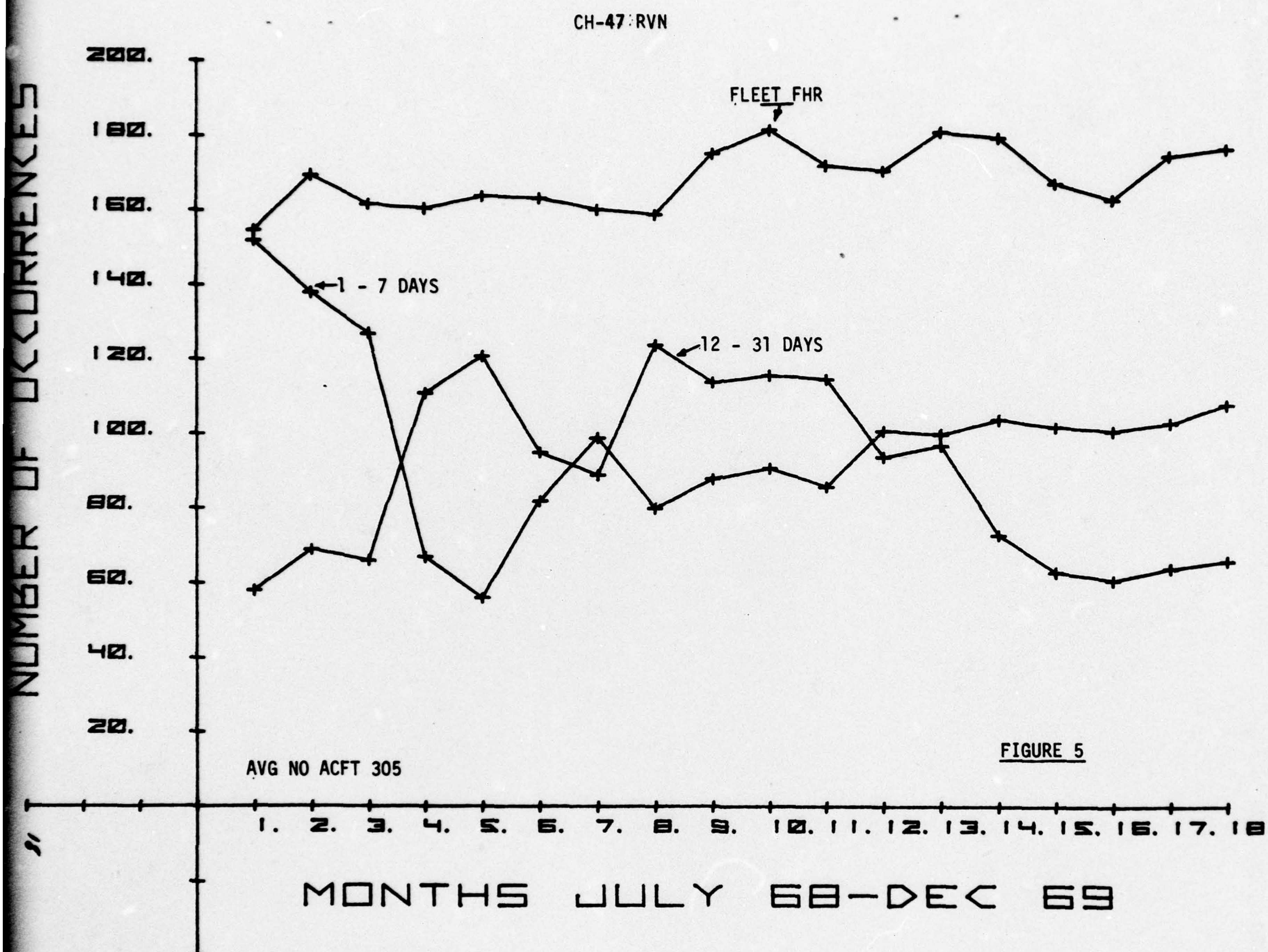

CH-47 RVN
NUMBER OF OCCURRENCES
200.
180.
160.
140.
120.
100.
80.
60.
40.
20.
FLEET FHR
1 - 7 DAYS
12 - 31 DAYS
AVG NO ACFT 305
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18
MONTHS JULY 68-DEC 69

FIGURE 5

VIII. FINDINGS AND DISCUSSION: FLYING/MAINTENANCE CORRELATIONS

Figure 6 is an idealized graphic representation of the rationale for the unexpected associations of low flying hour rates with high rates of maintenance and repair occurrences cited in Section I of this report. This illustration relates the exact findings of Reference 1 (Figure 1) to the observations of Section IV thru VII of this report. Specifically, the left-hand portion of the inverted parabolic model demonstrates the results of cut-and-fill maintenance management feasible during peace time, while the right-hand portion of the model shows the coordinated linking of flight and maintenance operations required to sustain combat flight hour rates.

The rationale illustrated in Figure 6 may also be referred to in explanation of poor-to-marginal correlation models of flying hours rates and the monthly number of "repair" events exceeding the time limits of AR 750-1. The deliberate decoupling of repairs from flight operations results in associations of monthly "highs" with "lows" that are unpredictable in their timing, frequency, and relative numerical magnitude. These elements of randomness are reflected in low values of R^2 attaching to the models, and in data displays that resemble buckshot patterns.

The left-hand portion of the trace in Figure 6 is thus seen as evidence of deliberate maintenance support management policies, rather than as evidence of an inherent need that aircraft may experience for flight. While some "tinkeritis" - an alledgedly irrepressible urge of ground personnel to "fix" any machine they can lay their hands on - may be involved in all maintenance activities, it is seriously doubted that Army aircraft are routinely taken apart simply because they are grounded. It is also unlikely that

infrequently flown aircraft rust, rot, or dry-out to a degree sufficient to account for the observed associations of low monthly flying hours with extremely high monthly rates of longer-term maintenance occurrences. It is proposed that Figure 6 be accepted as a valid representation and model of real-life operational conditions.

GROSS SALES RATE/FLIGHT RATE INTERACTION

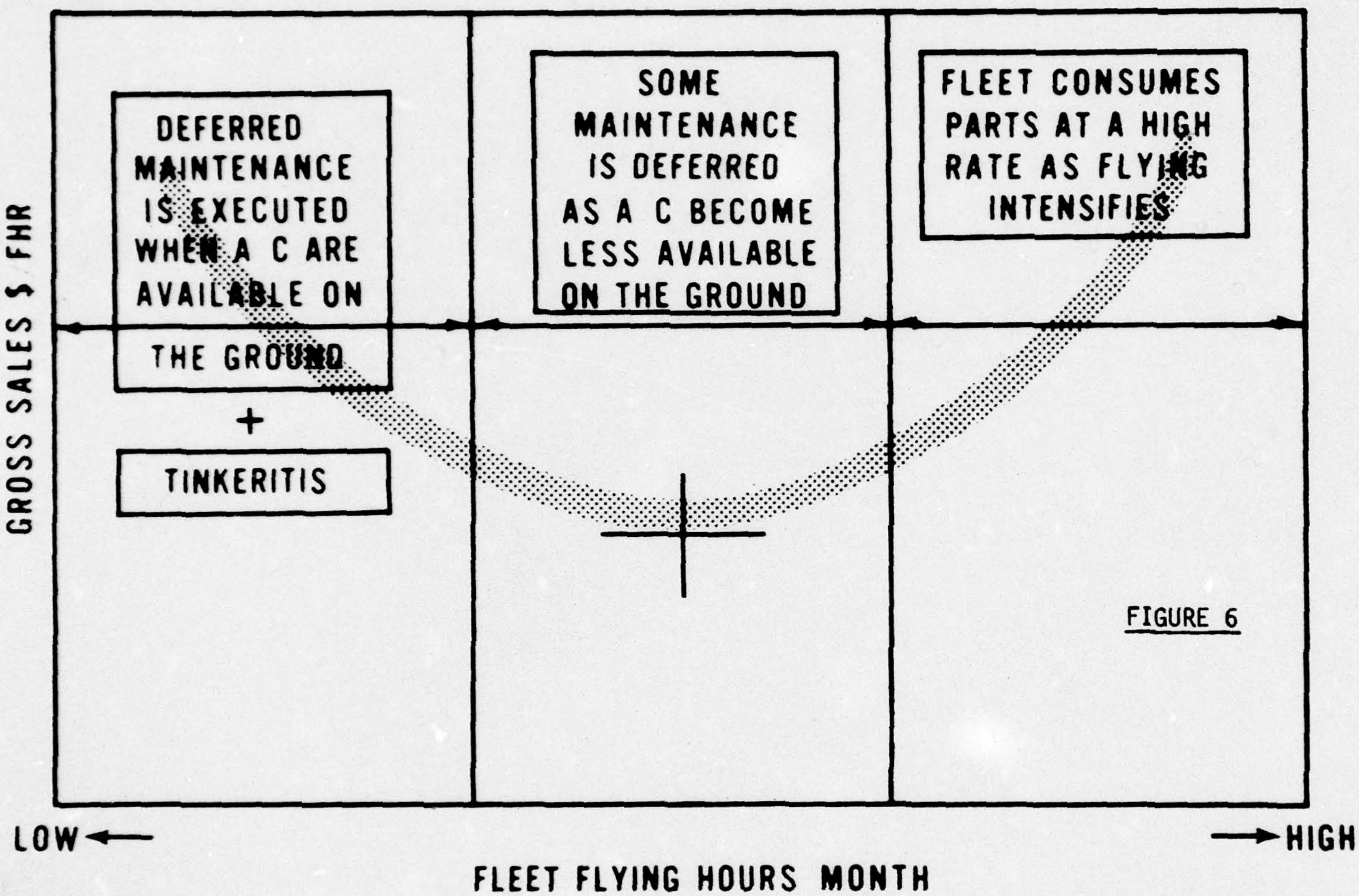


FIGURE 6

IX. FINDINGS AND DISCUSSION: INTERACTIVE COST/OPERATIONS MODELS

This section is devoted to a review of presumed interactions of maintenance and repair operations with stock-funded airframe parts sales to the field, and to the correlation of those maintenance activities with average monthly flight hour rates during the PEACETIME period July 1974 thru December 1975. The objective of discussions following is to explore and to illustrate the nature, scope, and limitations of interactive models corresponding to hypotheses a and b set forth in Section II of this report.

A. AH-1 AIRFRAMES WORLDWIDE

Mathematical models computed in relation to Figure 2 and shown at Section IV of this report may be "converted" into a format which takes into account the deployment density of the AH-1 fleet during the study period. Specifically, fleet flying hours per month are divided by the average monthly count of gunships to yield the Average Flying Hours per Aircraft per Month shown at Figures 7 and 8 (AVG FHR/ACFT/MO). It is noted that the model at Figure 7 corresponds to the "parabolic" model of Section IV, paragraph a, and that the model at Figure 8 corresponds to the "parabolic" model of Section IV, paragraph b. The R^2 values of the converted models, respectively 0.36 and 0.03, closely match those of their "parent models" which were, respectively, 0.46 and 0.05.

Figure 9 introduces (monthly) gross sales dollar amounts displayed as a trace sharing a common time scale with "maintenance" and "repair" occurrence count representations. It is noted that the extreme peaks of that trace in months #4 (Oct 74) and #7 (Jan 75) correspond to two non-routine events: an initial provisioning issue of parts to the Government of Iran

and a one-time delivery of GFP to the Bell Helicopter Company for the modification of AH-1G gunships to the AH-1Q configuration. Relating to the "normal" months #8 thru #18 (Feb 75 - Dec 75) the model of Figure 10 may be computed, expressing the closely correlated (R^2 = 0.85) and highly significant (99%) relationship between gross sales and the monthly count of "maintenance" events. In marked contrast, the contemporaneous model illustrated in Figure 11 expresses the absence of correlation between "repair" monthly counts and stock-funded parts figures (R^2 = 0.05). It is inferred from these models that stock-funded airframe parts sold during the study period were used primarily in support of AH-1 short-term (1 - 7 days) maintenance activities. It is also inferred that the dominant longer-duration "repair" events (8 - 31 days) are labor-intensive, rather than parts-intensive, during peacetime, and that they are deliberately managed to fully occupy the available work force.

During the RVN combat period illustrated in Figure 3, it is conjectured that the dominant 1 - 7 days "maintenance" occurrences were also the primary consumers of new and overhauled parts, that airframe "repair" activities in the field were sharply curtailed, and that the bulk of available labor hours were dedicated to the removal and installation of parts, assemblies, and sub-assemblies.

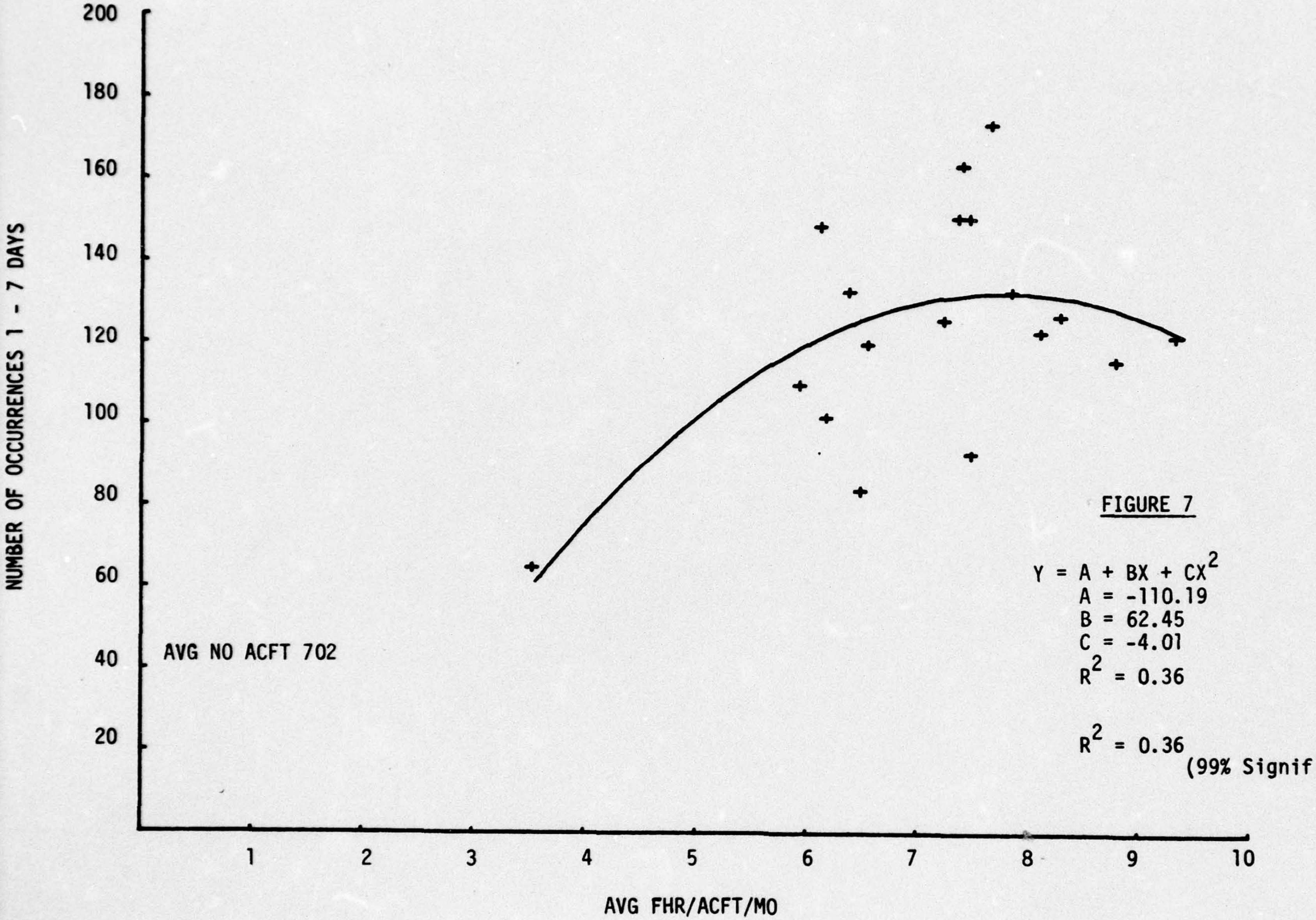
Two types of interactive models may be used for the purpose of estimating/predicting the dollar values of AH-1 airframe spare parts, given specific flying hours programs and deployment densities in selected theaters or worldwide. Both of these models are limited to peacetime periods, and computed dollar amounts must be adjusted for inflation relative to the 1974 - 1975

baseline of this study. The first of these models requires a two-step approach: utilization of Figure 7 to determine the "number of occurrences 1 - 7 days" corresponding to given (x) values of "AVG FHR/ACFT/MO," followed by utilization of Figure 10 to determine the "GROSS SALES" monthly figures corresponding to each previously computed "NUMBER OF OCCURRENCES 1 - 7 DAYS." This model explicitly follows the cause-and-effect sequence of hypotheses a and b and is flexible in that it may be used for sensitivity studies.

The second interactive model makes use of the relationships illustrated in Figure 12. This parabolic model was constructed via a correlation optimization exercise in which contemporaneous traces of fleet flying hours and monthly gross sales of airframe parts were "slid" past each other and successive month-on-month correlation models were computed. The model shown was selected for its R^2 of 0.70 (99% significance level), the highest Index value computed. It is noted that the joint data for Oct 74 and Jan 75 was not considered, to avoid distortion of the model by non-routine sales activities. This interactive model obscures the relationships of flight, short-duration maintenance, and parts consumption. This model also requires acceptance of a purported delay of three months between flight operations and sales which may or may not be a "norm" during periods other than that of this study. For the above reasons, use of this model is NOT recommended.

AH-1 WORLDWIDE

JULY 1974 - DECEMBER 1975



AH-1 WORLDWIDE

JULY 1974 - DECEMBER 1975

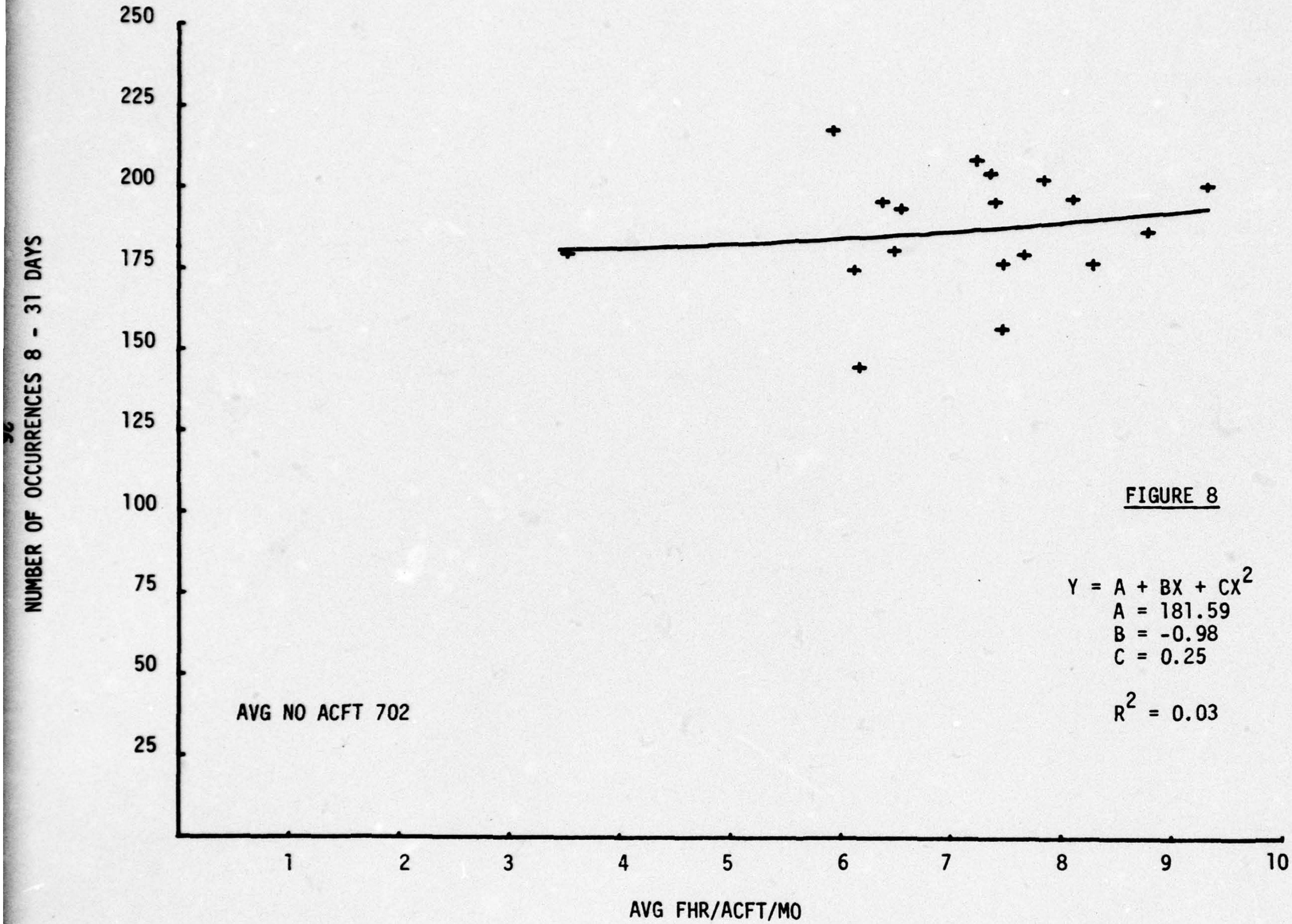


FIGURE 8

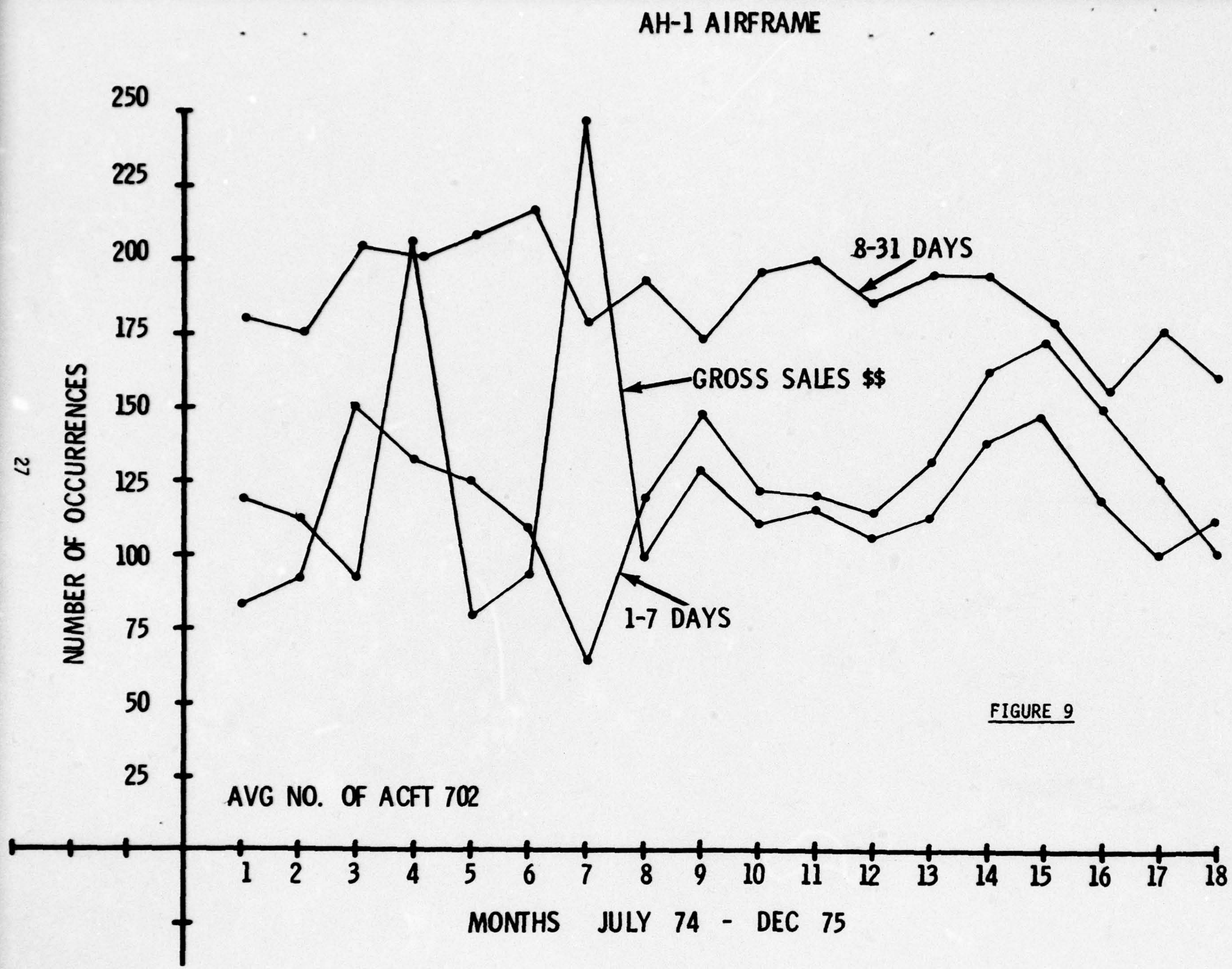

AH-1 AIRFRAME
250
225
200
175
150
125
100
75
50
25
NUMBER OF OCCURRENCES
8-31 DAYS
GROSS SALES $$
1-7 DAYS
AVG NO. OF ACFT 702
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
MONTHS JULY 74 - DEC 75

FIGURE 9

AH-1 AIRFRAME

WORLDWIDE

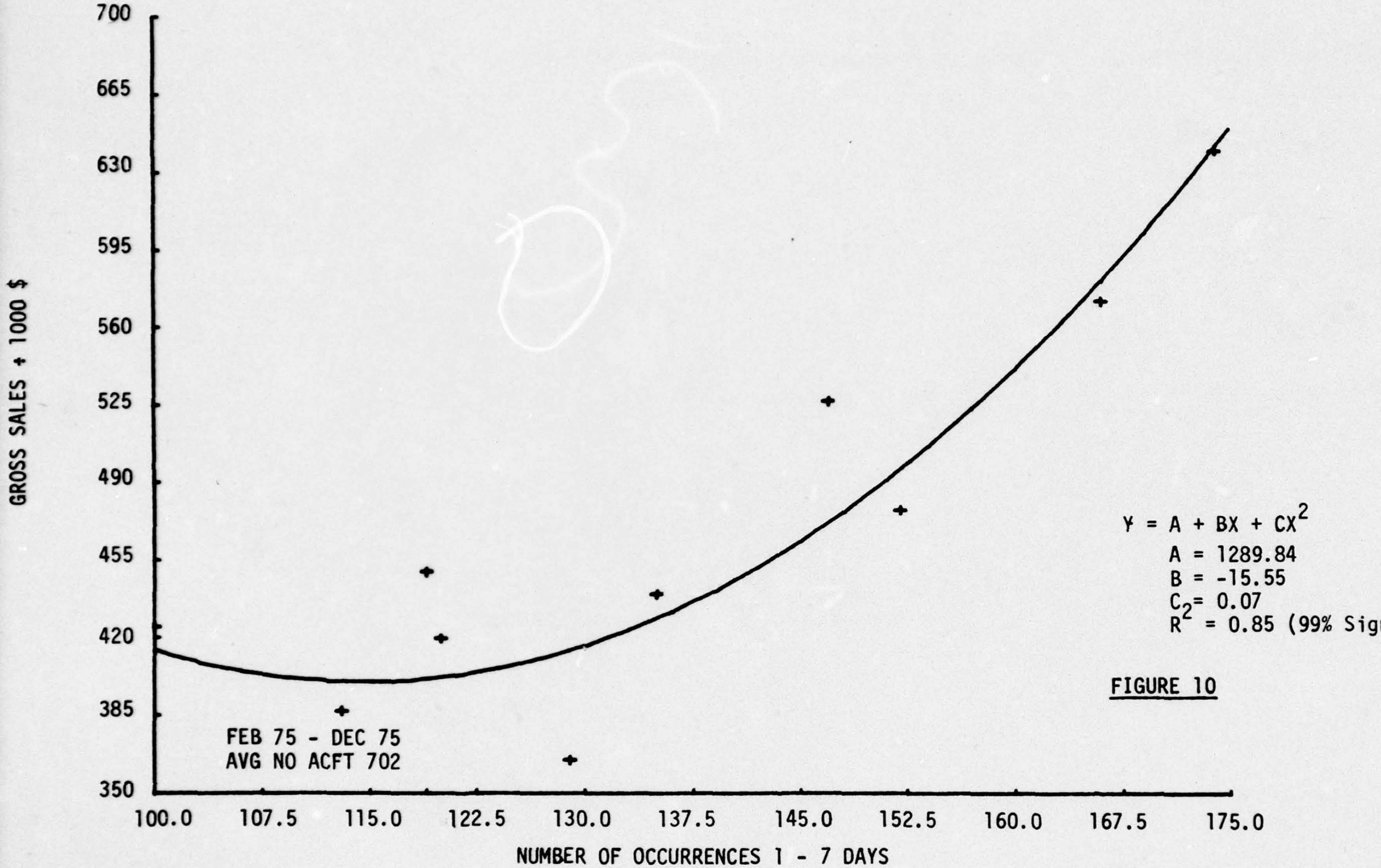


FIGURE 10

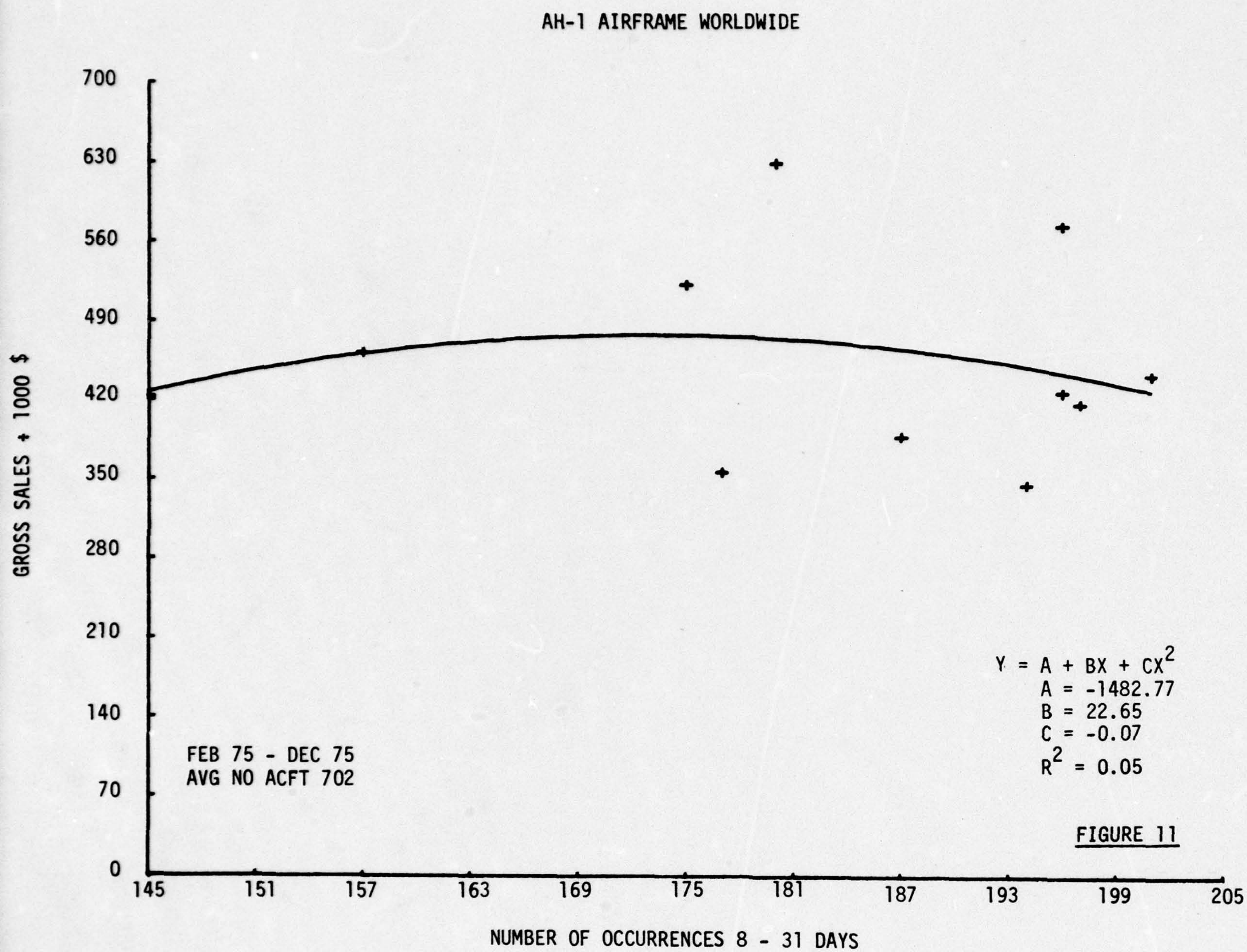

AH-1 AIRFRAME WORLDWIDE
GROSS SALES ÷ 1000 $
700
630
560
490
420
350
280
210
140
70
0
145
151
157
163
169
175
181
187
193
199
205
NUMBER OF OCCURRENCES 8 - 31 DAYS
FEB 75 - DEC 75
AVG NO ACFT 702
$Y = A + BX + CX^2$
A = -1482.77
B = 22.65
C = -0.07
$R^2 = 0.05$

FIGURE 11

AH-1 AIRFRAME WORLDWIDE

JUL 74 - DEC 75

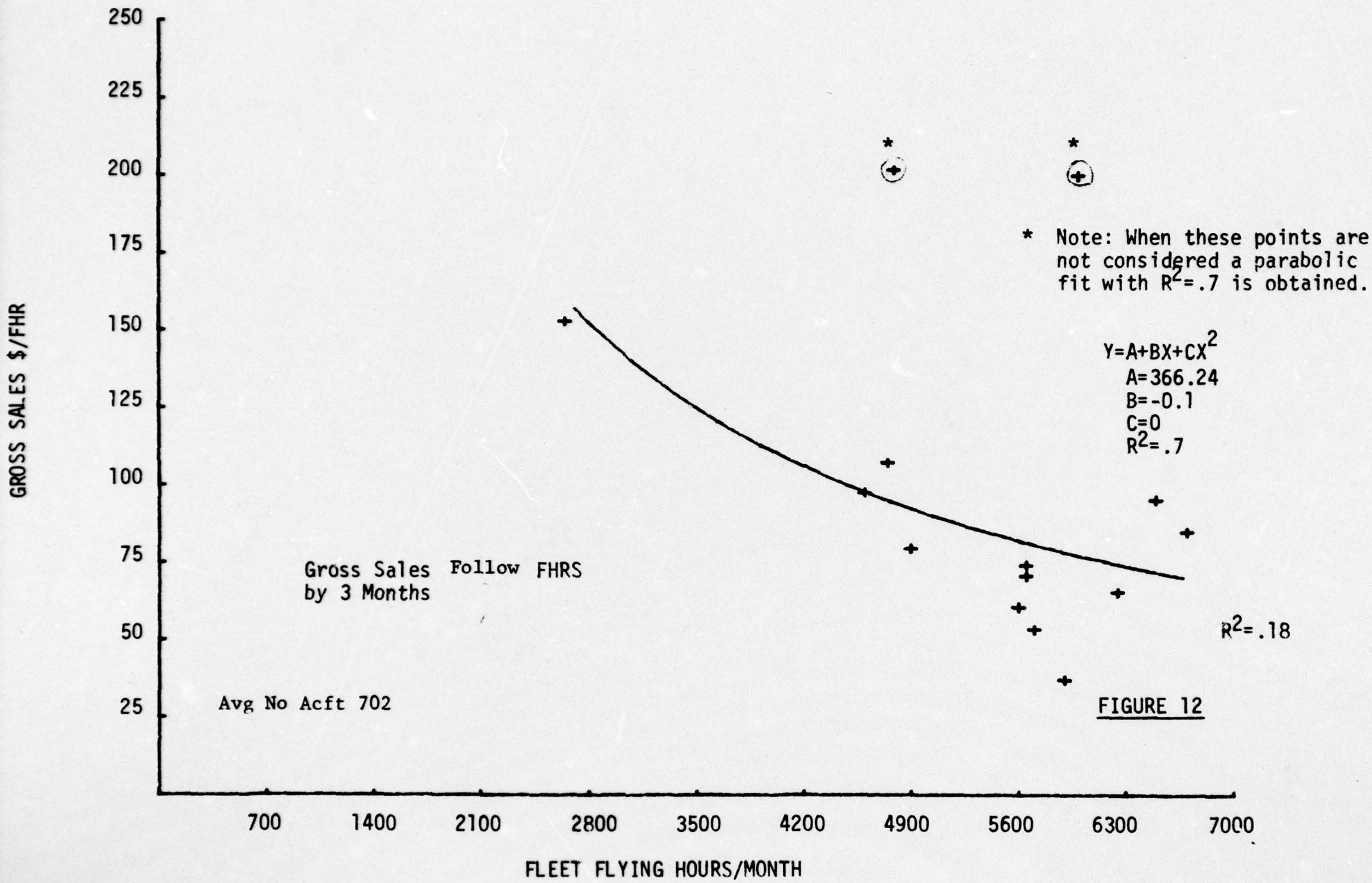


FIGURE 12

B. CH-47 AIRFRAMES WORLDWIDE

Mathematical models computed in relation to Figure 4 and shown at Section VI of this report are also "convertible" into a density-sensitive format. Figures 13 and 14 display converted data and curvefit traces, as well as models relating, respectively, "repair" event and "maintenance" event counts to "AVG FHR/ACFT/MO," the average flying hour rates. It is noted that the model at Figure 13 corresponds to the "parabolic" model of Section VI, paragraph b, and that the "A" model at Figure 14 corresponds to the "parabolic" model of paragraph c. The R^2 values of the new models, respectively 0.25 and 0.00, match the corresponding 0.25 and 0.03 R^2 values of their "parent models."

Figure 15 displays gross sales dollar amounts displayed as a trace sharing a common time scale with "maintenance" and "repair" occurrence count representations. The sales representation is shifted with respect to the "maintenance" and "repair" traces so as to increase their chronological correlation: gross sales in July 1974 are associated with August 1974 events, and so on. This graphic shift may reflect preplanning on the part of CH-47 equipped units, with parts purchases designed to preposition needed supplies prior to, or concurrent with, anticipated maintenance support activities. It is noted that the relative shift is based primarily on the period February 1975 thru December 1975, months #8 thru #18. During that period gross sales and "maintenance" occurrence count "peaks" coincide at months #8, #10, #16, and #17, and "lows" coincide at months #9, #11, #15, and #18. During that same period gross sales and 8 - 31 days events count "peaks" coincide at months #13, #16, and #17, and common "lows" appear at months #9 and #18.

Relating to the above period of apparent covariance, the model of Figure 16 may be computed, expressing a highly significant (99%) and closely correlated ($R^2 = 0.63$) relationship between monthly gross sales dollars and the count of "maintenance" events. The contemporaneous model shown at Figure 17 indicates non-existent correlation ($R^2 = 0.11$) between the monthly gross sales amounts and "repair" occurrences. Extension of the correlation period to eighteen months (July 1974 thru December 1975), coupled with an opposite chronological shift of repair events with respect to stock fund expenditures, increases the R^2 value to 0.24 for the model shown at Figure 18. While the chronological precedence of repair activities is not unusual (parts may be ordered to replenish field stock depleted as a result of maintenance work), the reversal of sequences and the still-poor correlation coefficient indicate that both Figure 17 and Figure 18 models are statistically non-significant. It is inferred from the preceding discussion and evidence that shock-funded CH-47 airframe parts sold during the study period were used primarily in conjunction with short-term (1 - 7 days) maintenance activities. As before, (see sub-section A), it is further inferred that the dominant "repair" activities are labor-intensive operations, and absorb only an insignificant (but unknown) fraction of airframe parts sold to the field. It is conjectured that these repair operations are managed to fully occupy the available complement of mechanics and metal-benders.

As set forth in sub-section A with reference to AH-1 systems, it is possible to construct two types of interactive models for predicting/ estimating the dollar values of CH-47 airframe parts needed in the field. Both of these models are limited to peacetime periods, and computed dollar

amounts must be adjusted for inflation relative to the 1974 - 1975 baseline of this study. The first of these models requires utilization of Figure 14, MODEL B (R^2 = 0.24) to determine the number of maintenance occurrences of 1 - 7 days duration corresponding to selected (given) values of "AVG FHR/ ACFT/MO," followed by utilization of Figure 16 to compute the monthly "GROSS SALES" amounts corresponding to each previously computed "NUMBER OF OCCURRENCES 1 - 7 DAYS." This two-step model reproduces faithfully the sequence of events described by hypotheses a and b of Section II. It must be emphasized, however, that the R^2 value of 0.24 makes the model of Figure 14 relatively unreliable between flight rates from 8 to 12 hours/aircraft/month, and totally unreliable below or above those rates. The model utilization sequence described above may be executed only with these considerations in mind.

The second interactive model is illustrated in Figure 19. The expressed relationship is derived from the juxtaposition of "FLEET FLYING HOURS/MONTH" and monthly "GROSS SALES $/FLYING HOUR" data, with a one-month offset. The flying hours of July 1974 were related to the gross sales of August 1974, and so on, implying sales in support of field stock replenishment and/or in support of anticipated flight and maintenance activities. It is noted that in relation to Figures 13, 14, 16, 17 and 18, the sequence of activities appears to have involved a combination of sales to the field both (one month) before and (one month) after each month of flight and "maintenance/repair" operations. The model of Figure 19, like that of Figure 12, obscures the cause-and-effect relationships of flight, short-duration maintenance events frequency, and parts sales and consumption in the field. The model's R^2

value of 0.34 is, moreover, sufficiently low to discourage utilization of the expressed relationship for predictive purposes.

It is concluded that both of the above interactive models are quantitatively inaccurate and statistically unreliable. It is conjectured that this unreliability is the result of both the complexity of field and NICP operations sequencing, and of the deliberate, thorough, "decoupling" of CH-47 systems flight and maintenance support activities.

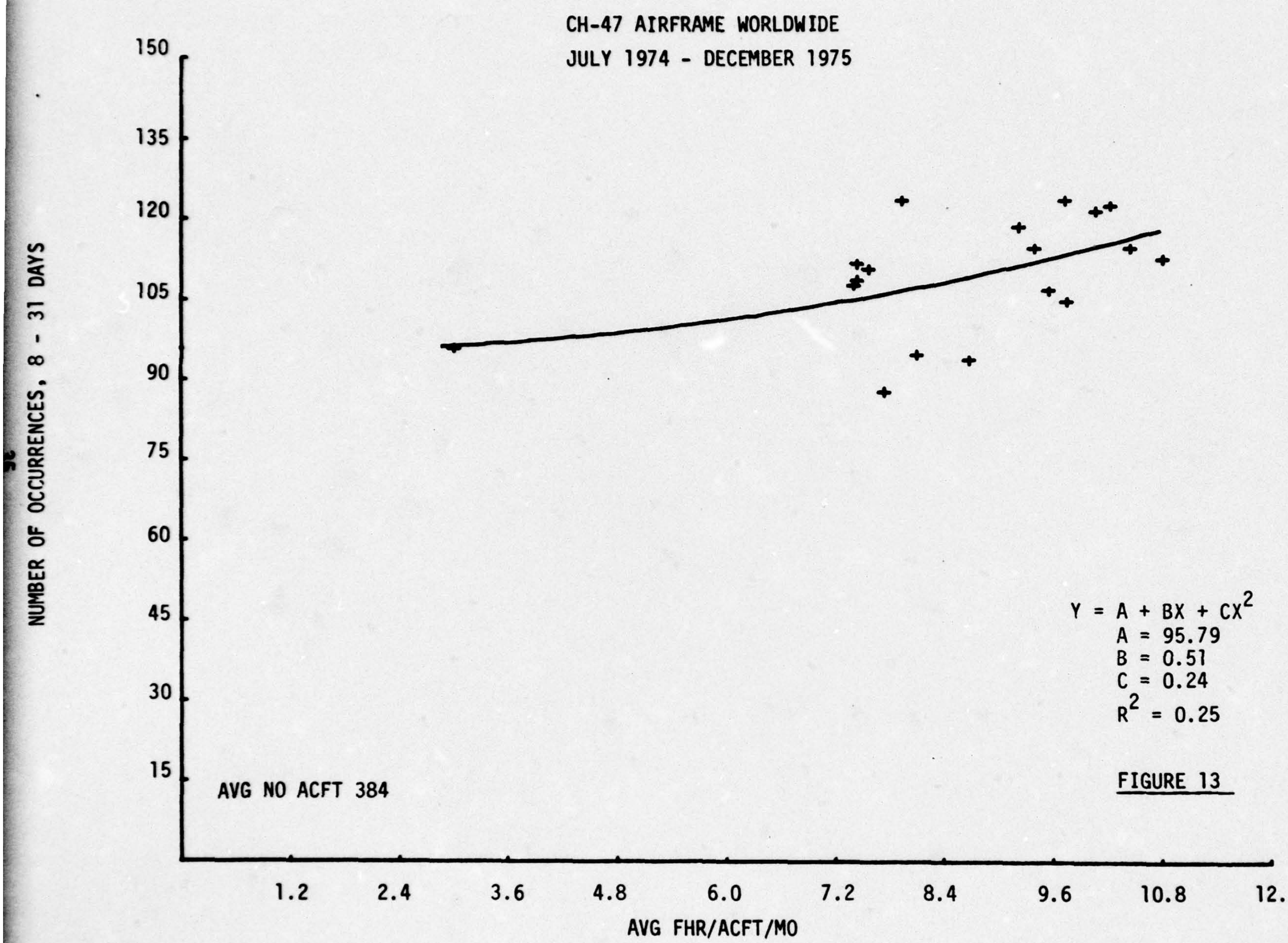

CH-47 AIRFRAME WORLDWIDE
JULY 1974 - DECEMBER 1975
NUMBER OF OCCURRENCES, 8 - 31 DAYS
150
135
120
105
90
75
60
45
30
15
AVG NO ACFT 384
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
12.
AVG FHR/ACFT/MO
Y = A + BX + CX2
A = 95.79
B = 0.51
C = 0.24
R2 = 0.25

FIGURE 13

CH-47 AIRFRAME WORLDWIDE

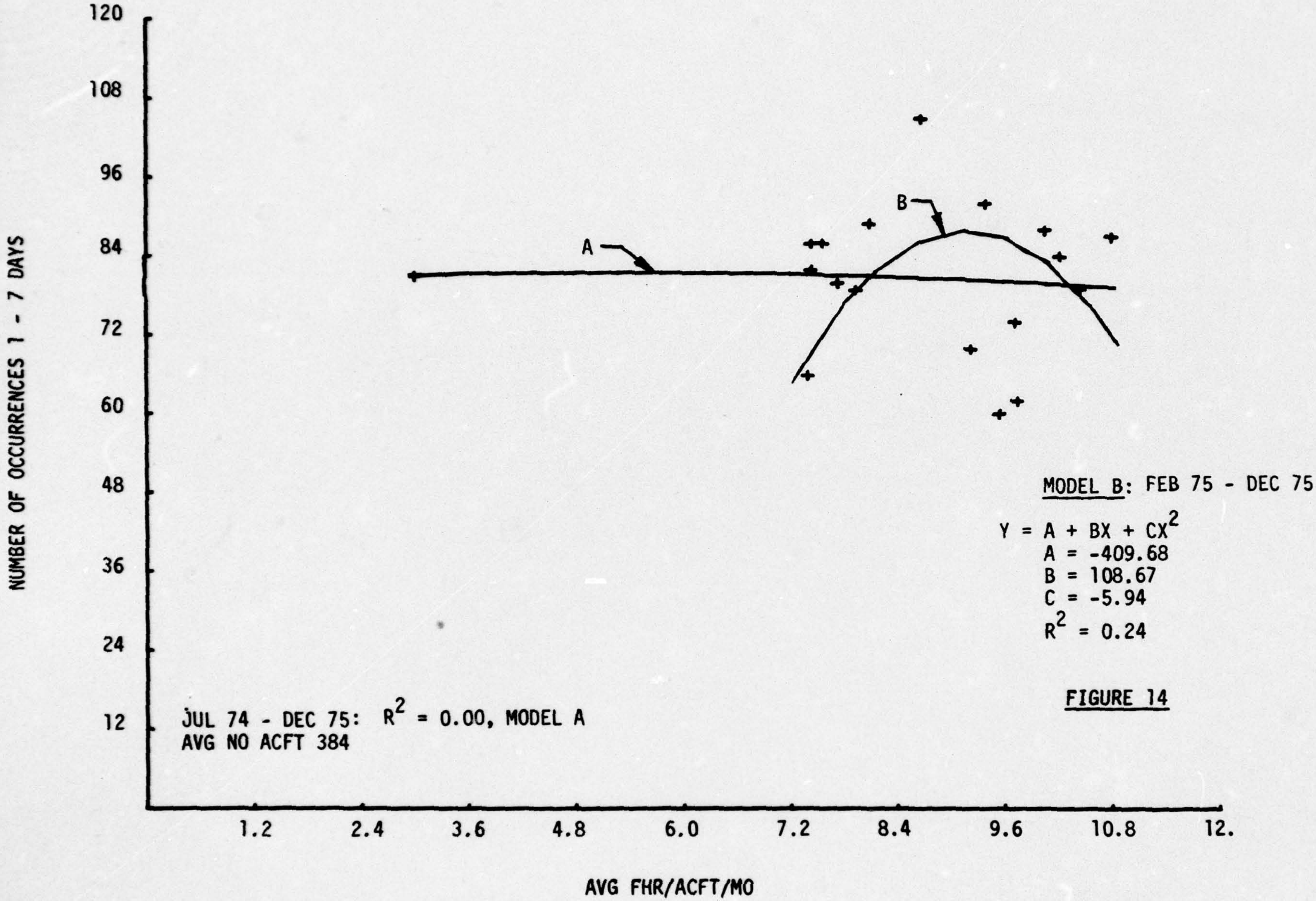
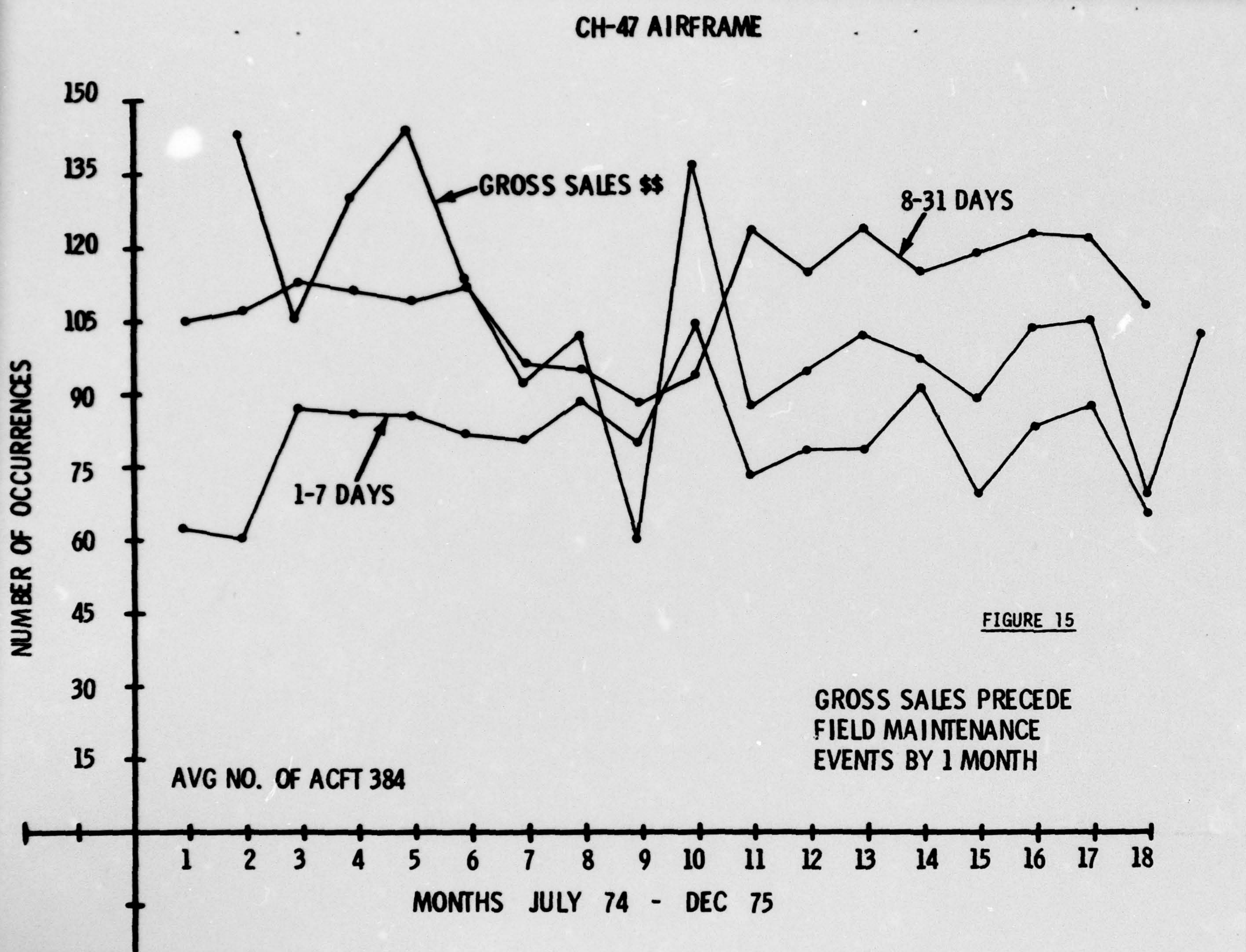


FIGURE 14



CH-47 AIRFRAME
GROSS SALES $$
8-31 DAYS
1-7 DAYS
NUMBER OF OCCURRENCES
150
135
120
105
90
75
60
45
30
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
MONTHS JULY 74 - DEC 75
AVG NO. OF ACFT 384
GROSS SALES PRECEDE
FIELD MAINTENANCE
EVENTS BY 1 MONTH

FIGURE 15

CH-47 AIRFRAME WORLDWIDE

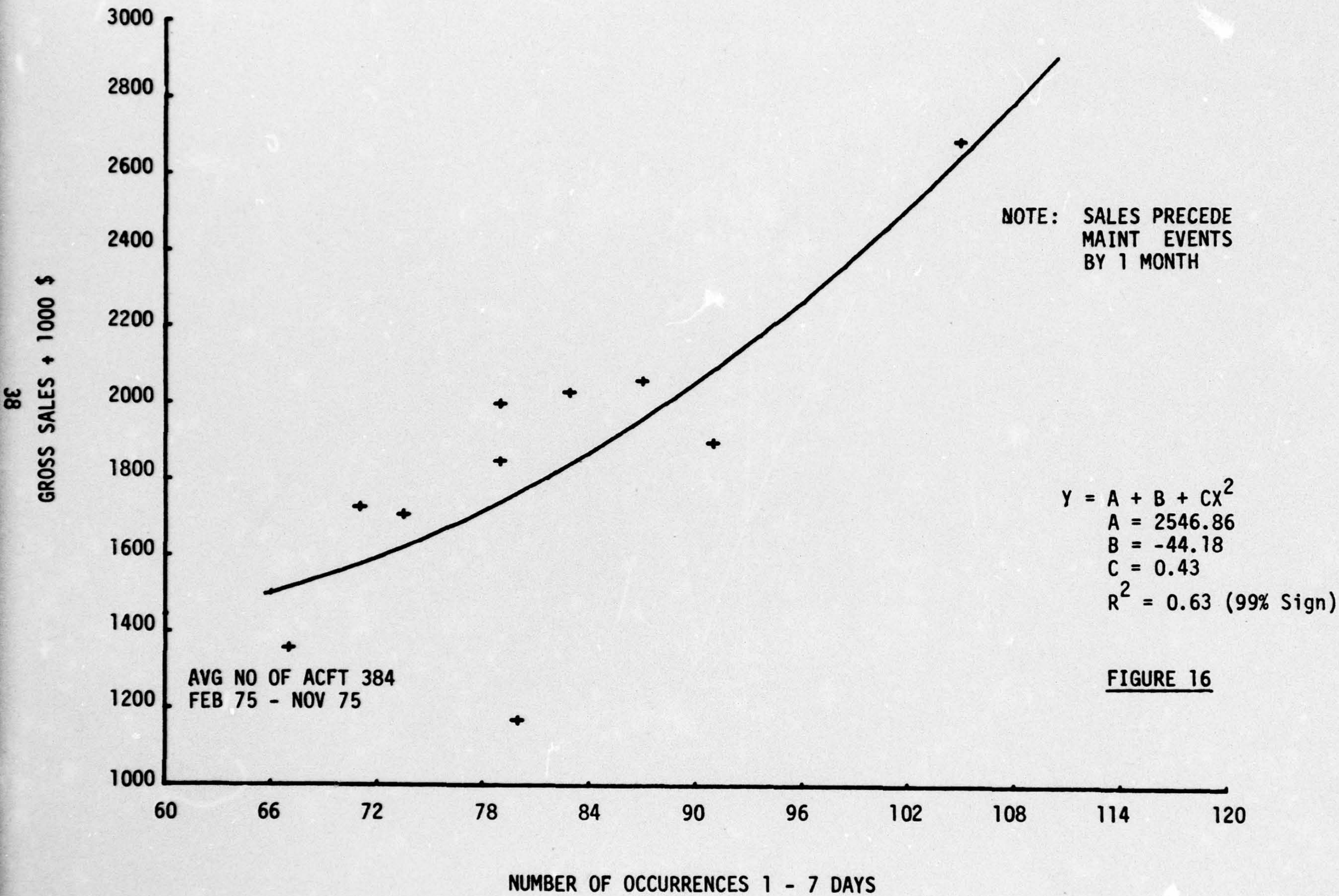


FIGURE 16

CH-47 AIRFRAME WORLDWIDE

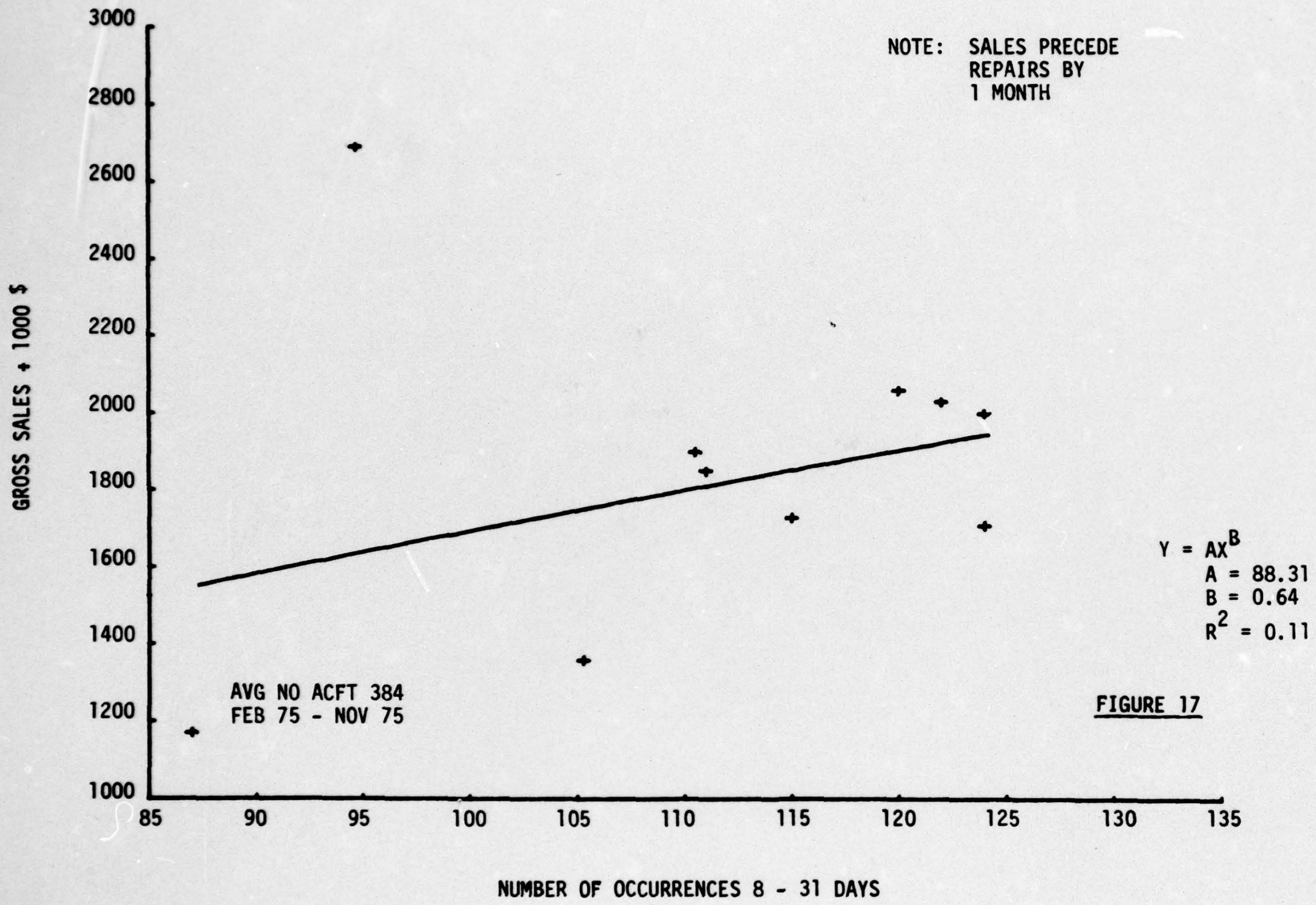


FIGURE 17

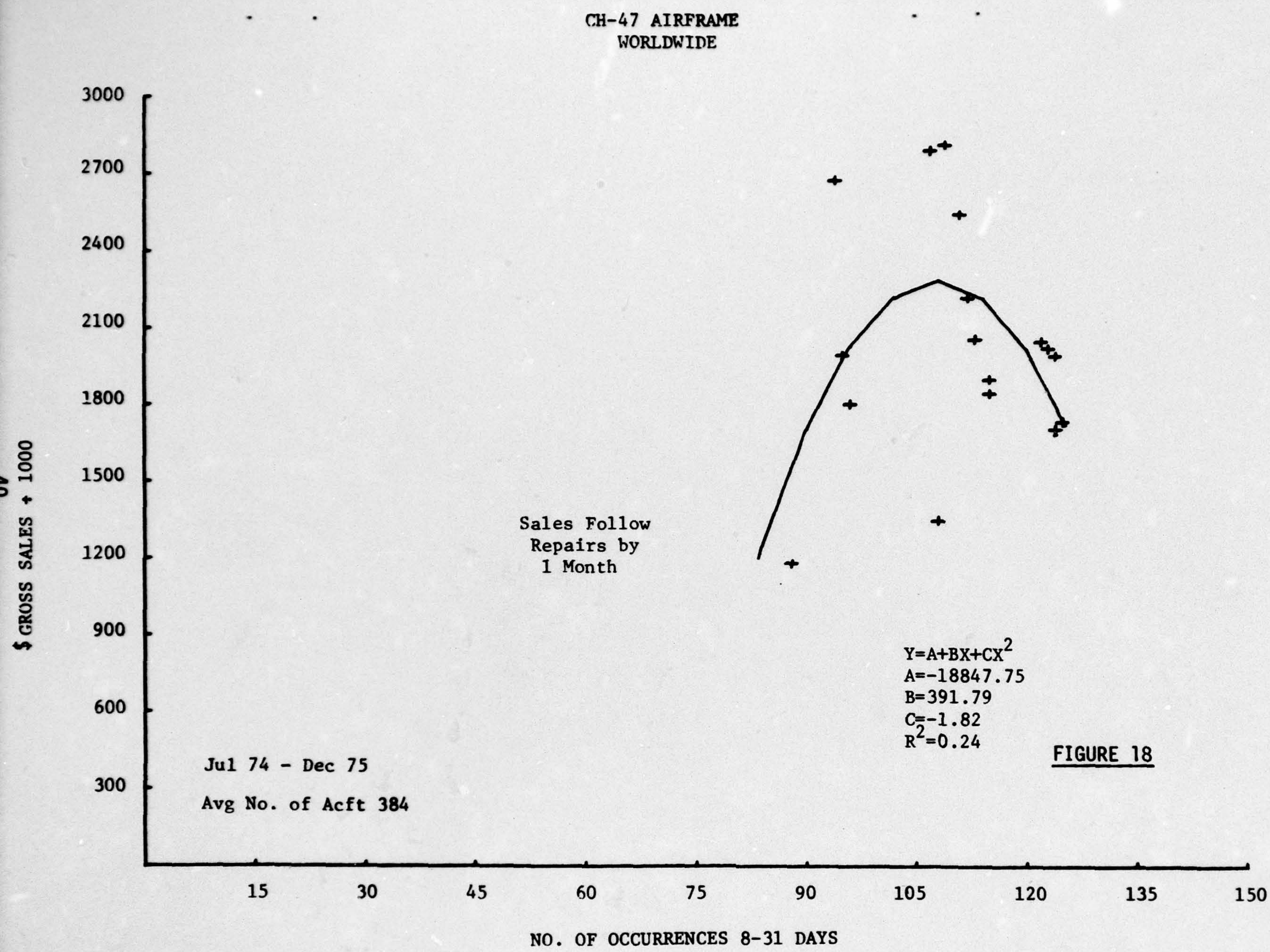

CH-47 AIRFRAME
WORLDWIDE
$ GROSS SALES ÷ 1000
3000
2700
2400
2100
1800
1500
1200
900
600
300
15
30
45
60
75
90
105
120
135
150
NO. OF OCCURRENCES 8-31 DAYS
Sales Follow Repairs by 1 Month
Y=A+BX+CX²
A=-18847.75
B=391.79
C=-1.82
R²=0.24
Jul 74 - Dec 75
Avg No. of Acft 384

FIGURE 18

CH-47 AIRFRAME WORLDWIDE

JUL 74 - DEC 75

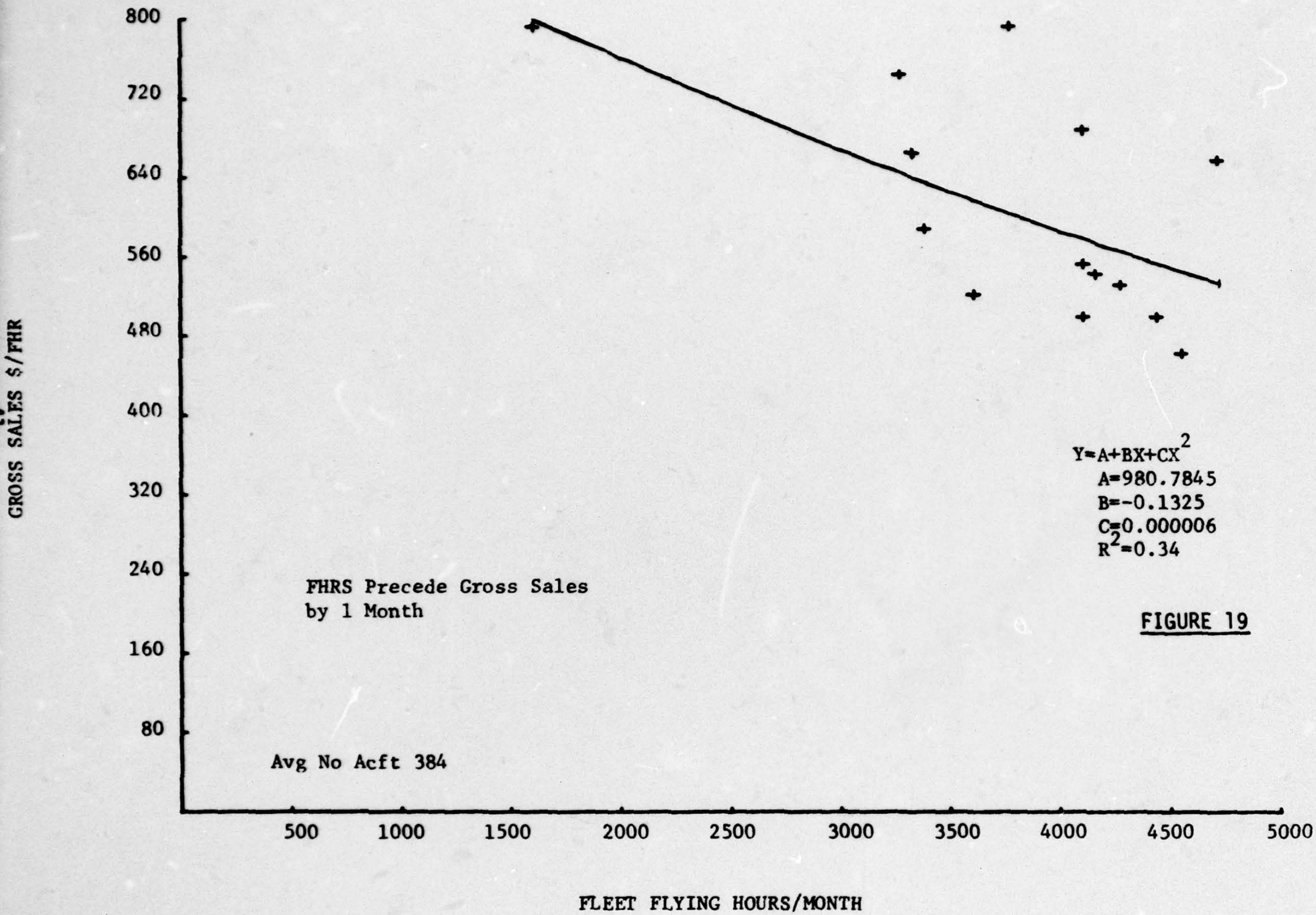


FIGURE 19

X. ON-CONDITION MAINTENANCE AND FIELD OPERATIONS

During the July 1974 thru December 1975 period of this study, USAAVSCOM teams of expert technicians have visited Army installations worldwide for the purpose of rating deployed aircraft as depot overhaul candidates. This inspection and assessment process is designated On-Condition Maintenance (OCM). Each individual machine is partially "dismantled," and the condition of specific airframe and mechanical components relative to established standards is recorded in an encoded format. Subsequently these condition codes are converted into numerical values which are summed-up and yield a Profile Index (PI) for each system. Finally, the PI's of each Model Designated Series (MDS) fleet are computer-sorted in ascending/descending order, and those serial numbered aircraft whose PI's exceed a preestablished "threshold" value become overhaul candidates. Subject to the field commanders' decision, the candidate aircraft are scheduled for depot maintenance and are removed from active units.

With reference to the AH-1 and CH-47 systems in PEACETIME, the indications of Section IV and VI are that the execution of most field maintenance activities is "decoupled" from their respective flying hour programs. "Cutting and Filling" is used to defer maintenance when flight hour rates are relatively high, and to "catch-up" on deferred maintenance when those rates drop. Since this pattern is tied to the pattern* of fleet flying hours during each fiscal/calendar year, it follows that transitions from "deferred" to

* See Section III of this Report

"catch-up" repair operations will occur predictably every June and November. It is conjectured that in those months the condition of deployed systems is most likely to be at low ebb, and that the OCM teams are most likely to find depot candidates in the field. Two admittedly tentative conclusions are, then, in order:

a. Since OCM teams are deployed at regular invervals for periods of 10 to 12 weeks, and sweep the world in an established geographic sequence, it must be expected that they will inspect and assess substantial portions of each fleet in the months of June and November. At those times, their visits will be most productive in terms of overhaul candidates. Conversely, team visits during March and August are likely to be least productive due to prior completion of "catch-up" repairs by field maintenance personnel; and

b. To the extent that active unit commanders are permitted to influence the timing of OCM team inspections, they can postpone such visits to coincide with the June and November transition points. The commanders are thus enabled to transfer some significant fraction of their deferred maintenance burden to the depots.

Taken together, the above conclusions signify that random and non-random "resonance" of OCM inspections and of field maintenance activities, notably longer-term repairs, is the norm rather than the exception. A positive view of these circumstances is warranted, in that they promote the distribution of maintenance work across all echelons, and contribute to the economic viability of a "warm base" maintained by the Army against wartime mobilization needs. Opportunities for cost savings, however, may exist unexploited,

through selective elimination of OCM team visits that are relatively unproductive year after year. Discovery and measurement of such low-yield visits in terms of timing and geographic location is outside the scope of this report, but is suitable for a separate cost-effectiveness type of study.

XI. CONCLUSIONS

The preceding findings and discussions are summarized in the following conclusions:

a. Fleet flying hour programs for first line Army aircraft systems are distributed across fiscal/calendar years in a repetitive, cyclical, pattern. This pattern is determined by the interaction of funding dynamics, (seasonal) weather variations, personnel availability, and military training exigencies.

b. The performance of short-term, 1 to 7 days' duration "maintenance," and of longer-term, 8 to 31 days' duration, "repairs" is purposefully managed during peace and war times. The frequency of these events/occurrences is adjusted to respond to mission and safety requirements on the one hand, and to match the workload capabilities of field personnel on the other. Key determinants of management policies and of support dynamics are funds availability and operational readiness (OR) standards.

c. Substantial differences exist between the managed maintenance support of AH-1 and of CH-47 systems in peace and war times, attributable at least in part to marked differences between the missions and the mechanical and structural complexity of these aircraft. The gunships appear to require a responsive correlation of short-term maintenance activities with flight operations, while the Chinooks appear to be served effectively by a rather steady, evenhanded, mix of short-term "maintenance" and of longer-term "repair" operations.

d. In peacetime there exists a marked "decoupling" of all maintenance support activities from the turbulent cyclical pattern of flight

hour rates. This purposeful disconnection of logistical support and of flight operations may result in random and non-random "resonances" of field "maintenance/repairs" with depot overhauls, via the OCM status assessment process. The perceived result of resonances is a redistribution of workloads forward in time, as well as "vertically" across all maintenance echelons. Study of these (postulated) resonances is recommended for the purpose of enhancing the cost-effectiveness of OCM field visits.

e. The sale of stock-funded airframe parts to the field, presumably for use in maintenance support activities, correlates well with the monthly rates of short-term, 1 to 7 days' duration, "maintenance" events, and poorly with the monthly frequencies of longer-term, 8 to 31 days' duration activities. It is concluded that the subject parts are used on a replacement basis to speed-up the support of flight operations in peace time. Presumably this is a correct assessment of parts utilization practices in war time as well.

f. Interactive models linking flight hour rates, short-term maintenance event frequencies, and (parts) gross sales dollar volumes are feasible. Such models are of value only for order-of-magnitude estimating purposes, notably for the CH-47 fleet. The statistical credibility of AH-1 two-step interactive model is fair-to-good.

g. Execution of this study has revealed considerable differences between the maintenance and supply support of AH-1 and CH-47 systems, as well as certain important commonalities. It is concluded that parallel studies of other first-line aircraft systems are warranted. The objective of such studies would be to determine whether the methodology used for the

ordering and re-ordering of stock-funded parts may be improved procedurally and economically.

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4. Memo, "Analysis of Annual Stock Fund Sales and Returns" St. Louis, MO: US Army Aviation Systems Command, Directorate for Materiel Management, Policies, Plans, and Programs Division (DRSAV-QP), 19 November 1976.

ACRONYMS

AH-1, AH-1G, AH-1Q:	Bell Helicopter Company-produced armed-escort helicopters ("COBRA"). See GUNSHIPS below.
AR:	Army Regulation(s)
CH-47:	Boeing-Vertol produced cargo/personnel carrier helicopters ("CHINOOK")
FAMF:	Floating Aircraft Maintenance Facility
FEBA:	Forward Edge (of) Battle Area
GFP:	Government Furnished Property
GUNSHIPS:	AH-1-type Aircraft ("COBRA")
HQ DA:	Headquarters, Department of the Army
NICP:	National Inventory Control Point
NORM:	Not Operationally Ready, Maintenance
NORS:	Not Operationally Ready, Supply
OR:	Operational Readiness
RVN:	Republic (of) Viet-Nam (Vietnam)
USAAVSCOM:	U.S. Army Aviation Systems Command

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